Finite Element Analysis is A Powerful Approach To Predictive Manufacturing Parameters

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Abstract

Analytical formulations that is extremely important by understanding how can prepare the manufacturing process and the optimization of machining parameters such as cutting conditions, and tool geometries which is led to reduce the experimental tests needful. Finite element model belong numerical simulation method which is considered natural extension of analytical formulations as established a special relation to develop detailed of models during manufacturing process. It can provide detailed information from machining process that is depending on the cutting conditions such as cutting speed, chip formation, stress-strain analysis, and feed rate. The calibration procedure was carried out of finite element model and validation by comparing the experimental results and the corresponding numerical simulation data. The results indicate there is a good agreement between simulated values and experimental tests which depend to investigate on two types that is calibration and validation. This is because the validation of numerical simulation model and analytical formulations which is verified only when they have conform to experimental results. It concludes that the finite element model represents the real key to reduce the cost of manufacturing in terms of machining time saving and extend the duration of the cutting tool life.

Keywords: Finite Element Analysis; Numerical Simulation Model; Computers Aided Engineering (CAE); Cutting force; Temperature distribution; Chip Formation.

الخلاصة:

الصيغ التحليلية التي هي في غاية الأهمية في فهم عملية التصنيع ولتحسين خواص معلمات القطع مثل ظروف و أداة القطع مما يؤدى إلى تقليل الاختبارات التجريبية المختبرية اللازمة. ان نمذجة العناصر تنتمي لطريقة المحاكاة العددية التي تعتبر امتدادا طبيعيا من الصيغ التحليلية وتؤسس لبناء علاقة خاصة لتطوير نماذج مفصلة و دقيقة خلال اجراء عملية التصنيع. ويمكن أن توفر معلومات مفصلة عن عملية القطع التي تعتمد على ظروف من اهمها سرعة القطع، وتشكيل الرقاقة، وتحليل الإجهاد والالتواء، ومعدل التغذية. نفذت عملية المعايرة ما بين نمذجة العناصر والتحقق من صحتها بمقارنة النتائج التجريبية المختبرية وبيانات المحاكاة العددية. تشير النتائج إلى وجود توافق جيد بين قيم المحاكاة والاختبارات التجريبية التي تعتمد على نوعين هما المعايرة والتحقق بينهما. ويرجع ذلك إلى ان التحقق من صحة نموذج المحاكاة العددية والتركيبات التحليلية التي تحققت قد اتفقت تماما مع النتائج التجريبية .ويستنتج من ذلك أن نمذجة العنصر يمثل المفتاح الحقيقي لخفض كلفة الانتاج من حيث توفير الوقت اللازم لعملية القطع واطالة عمر أداة القطع.

الكلمات المفتاحية: التحليل بأستخدام نمذجة العناصر، نموذج المحاكاة العددية، برمجة الحاسبات، قوى القطع ، توزيع درجات الحرارة ، تشكيل الرقائق.

1. Introduction

In the last few years, computers aided engineering (CAE) have been considered very important step by providing several numerical simulations software, which are already available for performing simulation process such as ABAQUS, ANSYS, DEFORM, FORG, MARC, COSMOS, etc. Hence, initial software simulation of finite element (FE) was made in 1964. In fact, engineers had to prepare data element by element and node by node because mesh generators were not available at that time. Therefore, a key punched IBM card represented each element and each node. However, for checking geometry and post process results were used batch mode line plots. Ultimately, the introduction of personal computers (PC) powerful sufficient to run finite element software supplies very cost influential problem solving. Nowadays, the hundreds of software simulation packages can choose from market (Moaz , 2015).

2. Numerical Simulation

Numerical simulation methods are natural extension of analytical formulations that is very important in the cutting processes comprehension and for the reduction of experimental tests needful with the optimization of tool geometries, cutting conditions, and other cutting response parameters which is employed in the numerical methods (Calamaz *et.al.*, 2008).

Finite element method belong numerical methods which use elements from analytical models as established relations to develop detailed models of cutting process. It can provide detailed information during the cutting process that is called machining parameters such as cutting force components, temperature distributions, and stress-strain analysis (Hamed *et.al.*, 2007). Regards to obtain accurate result, it is important to setup the suitable established relations which can be very labor intensive.

In fact, the most important characteristic of this study is focused on the massive and rapid development in the processes and methods that is used the finite element analysis. On the other hand, it is presented the validation of numerical simulation model and analytical analysis which is verified only when they conform to experimental work results. However, numerical models display capable replacements for experimental results by presenting detailed results and rapid as well. In this respect, finite element method (FEM) could help to avoid failure. Therefore, numerical methods are becoming influential technique to study manufacturing process. This research paper is presented the development of finite element method (FEM) procedure to predict machining parameters during cutting condition by estimating the cutting force components, chip formation, surface roughness and temperature distribution (Moaz *et.al.*, 2013).

3. Finite Element Analysis

Finite element analysis is considered key to find some of the items that difficult to be obtained from experimental tests such as stress, temperature distribution and strain. It can be used in machining process by modelling the cutting tool and work piece material into discrete elements interconnected at discrete node points (Mohad *et.al.,* 2012).

In fact, many application can benefit to get a better understanding of stress and strain distribution, chip formation, effect of cutting parameters, temperature distribution and observation of contact surface conditions. Furthermore, simulation analysis allows to create a model by using finite element method to predict the final output properties, enable the machining conditions to be monitored the micro scale cutting action in the cutting zone, and improve the machining process control (Mohad,2012; Mabrouki *et.al.*,2000; Mohd *et.al.*, 2012).

3.1 Finite Element Modeling (FEM)

Researchers which are used the finite element model based on Lagrangian formulation with explicit integration method that is considered as famous technique such as (Ozden and Elaheh,2011) developed 3D model by using commercial finite element software ABAQUS.

This model targets to simulate the drilling process by calculating the evolution and damage initiation as shown in figure (1). Also, it can predict cutting parameters such as cutting forces, stress distribution, torque in the work piece material throughout the drilling process.

(Mohd *et.al.,* 2012) designed a new FEM model is proposed to simulate machining in conventional and high pressure coolant supply. The effect of the coolant in relation to chip formation, thermal generation and cutting forces will be modelled using finite element modeling and coupled with FSI algorithm. The effect of the coolant pressure on chip formation, temperature generation and cutting force during the machining of Ti-6Al-4V alloy has been analyzed. The model enable further understanding of the effect of coolants in the cutting zone, such as chip breakage is shown in figure (2). It can be seen that the simulation presented segmented chip formation with the deformation of the chip being found to be inhomogeneous with periodic variation in thickness. On the other hand, the comparison has obtained of chip formation between simulation model and machining experiment of Ti-6Al-4V.

On the other hand, (List *et.al.,* 2005; Seshadri *et.al.,* 2013) focused on FEM of cutting process has proved immensely valuable in the manufacturing sector owing to its capabilities in regulating and optimizing the governing parameters of tooling and production systems. Actually, the FE tools have significantly improved the quality of the product, significantly reduced the cost of design changes and lead to saving time. FEM have studied the cutting characteristics of important alloys such as Aluminum.

(Diana and Sorin, 2014) used the finite element method through DEFORM 2D model to determine the dynamics of elastic-plastic or pure plastic deformation process is shown in figure (3). However, metal cutting processes theory and phenomena are explained by plastic deformation of the work-piece material. Therefore, the cutting process is considered a plastic deformation process, so it can say that conventional cutting of metals can be made through plastic deformation processes.

FEM technique is a good compliment with the advancement of recent computational speed to mechanistic approaches, experimental intensive and offer a reasonable insight to the cutting process for selection of machining parameters to avoid breakage and premature wear of the tool (Lai *et.al.*, 2008; Liu *et.al.*,2004; Jin *et.al.*,2012). Many researchers have used 2D and 3D models of finite element modeling process to study cutting forces or temperature distribution, chip formation and cutting tool wear under different process parameters (Umbrello,2008; Karpat,2011; Wu and Zhang,2014). For instance, (Özel *et.al.*, 2011) used FEM simulation to predict temperature distribution and wear development in micro-milling of Ti-6Al-4V alloy. (Tej *et.al.*,2015).

(Changyi and Yuhao,2014) were obtained the thermal process and mechanical process could be modelled and simulated simultaneously, and the elaborate temperature, stress, strain with respect to time and space could be solved. By using finite element method has been predicted a thermal distribution is shown in figure (4), cutting force, and chip formation on the affected zone of Ti-6Al-4V alloy work-piece (Yang *et.al.*, 2010). 2D model and 3D model were used to investigate the chip formation process and study the cutting force (Xi *et.al.*, 2014).

4. Results and Discussion

4.1 Calibration and Validation

The calibration procedure was carried out. Machining parameters and boundary conditions such as cutting speed, chip formation, stress, strain, and feed rate are considered very important for researchers to find the correct result by comparing between predicted values and experimental work results. Besides that, the calibration of finite element model was validated by comparing the experimental work results and the corresponding numerical simulation data. (Bordin *et.al.*,2015) were found the comparison between the experimental work and estimated result of cutting forces for dry and cryogenic machining as shown in figure (5).

(Moaz *et.al.*, 2013) found the finite element modeling can predict the feed cutting force in good agreement with the experimental results as shown in figure (6). In fact, several studies performed numerical simulation by using finite element method to investigate the effects of machining parameters. For instance, temperature distribution, coatings, and tool materials also effects of cutting speed, as well feed and depth of cut (Ma *et.al.*,2014). On the other hand, some investigations were focused on the chip formation mechanics in turning or milling. Figure (7) shows the results indicate there is a good agreement between simulated predicted values and experimental work results.

Finally, the results of the finite element method have been verified by comparing with the experimental work. For instance, it is shown very good agreement in terms of chip morphology, cutting forces. Furthermore, contribute in reducing the cost of manufacturing in terms of machining time saving and extend the duration of the cutting tool life.

5. Conclusion

This research paper presents a numerical simulation model by using finite element analysis. It could help to avoid failure and saving machining times by predicting the machining parameters such as cutting forces, chip formation, and temperatures distribution. This is because researchers are focused to reduce the experimental tests, the cost of manufacturing, which is led to increase the productivity and the quality of machined parts. However, the result is found that there is very good agreement between the simulated values and experimental tests. Therefore, finite element method is useful to predict the machining properties and enable to reduce the cost of manufacturing, as well as to improve quality the cutting process control.

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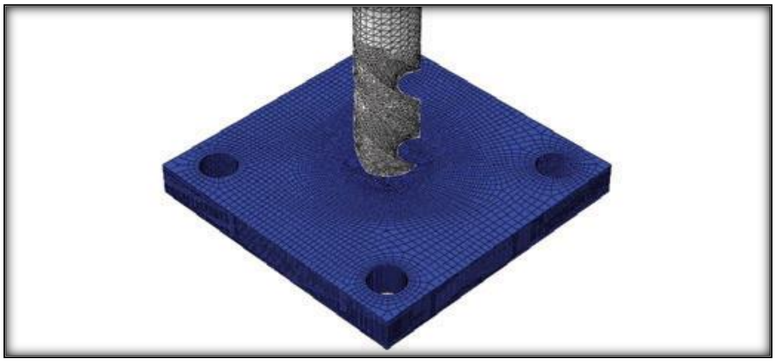

Figure 1. The Model Targets to Simulate The Drilling Process (Ozden and Elaheh ,2011).

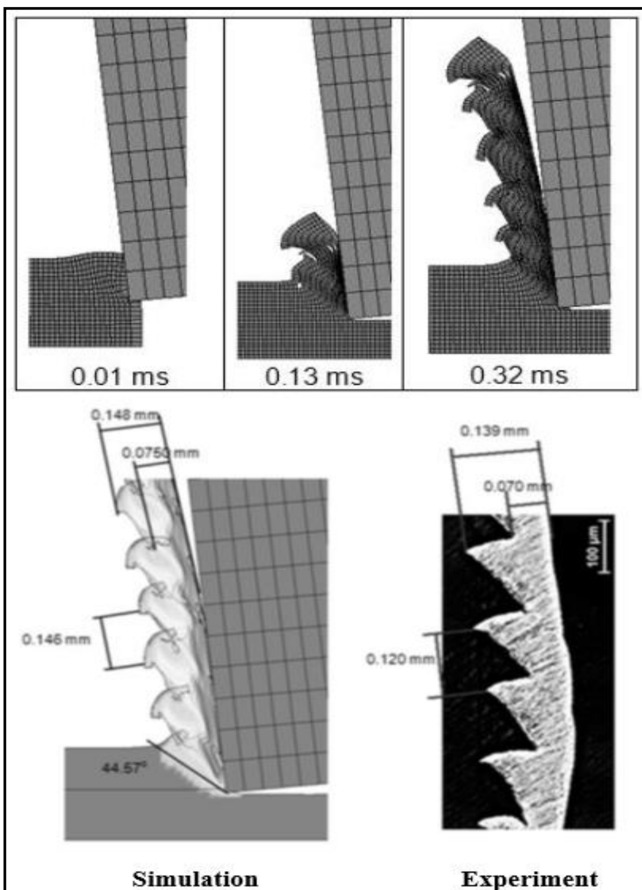

Figure 2. Simulation and Machining Experiment Presented Segmented Chip Formation (Mohd *et.al.,* 2012).

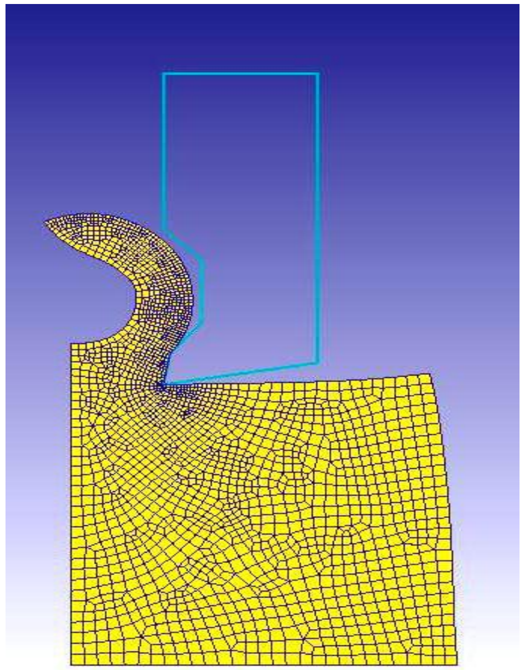

Figure 3. Simulation of Work-Piece Clamping for Studied Cases by Means of Border Conditions (DEFORM 2D).

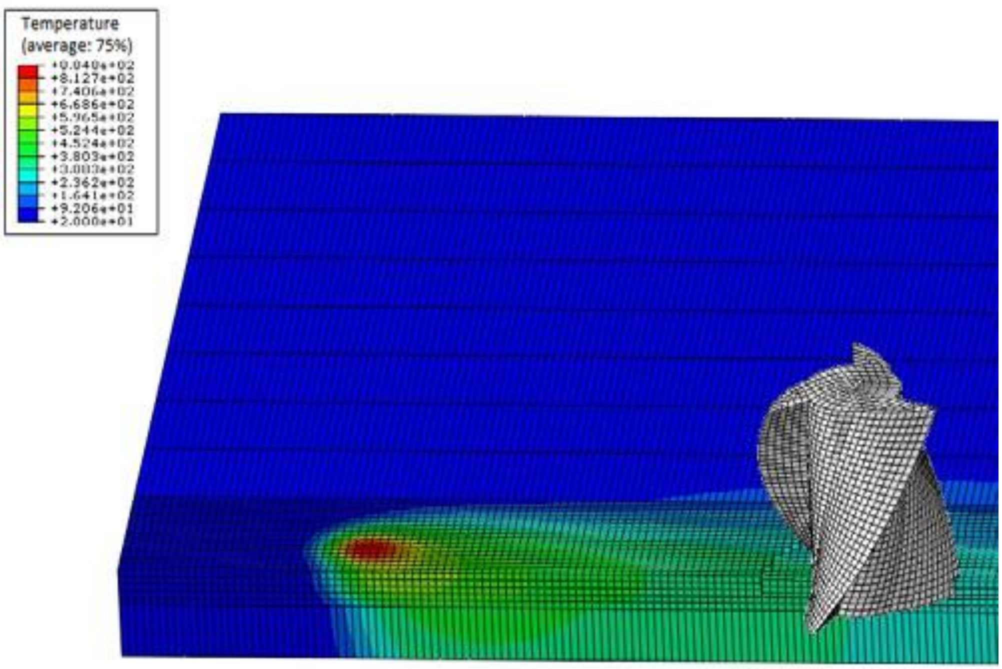

Figure 4. Temperature Field of The Laser Assisted Milling Simulation (Changyi and Yuhao ,2014).

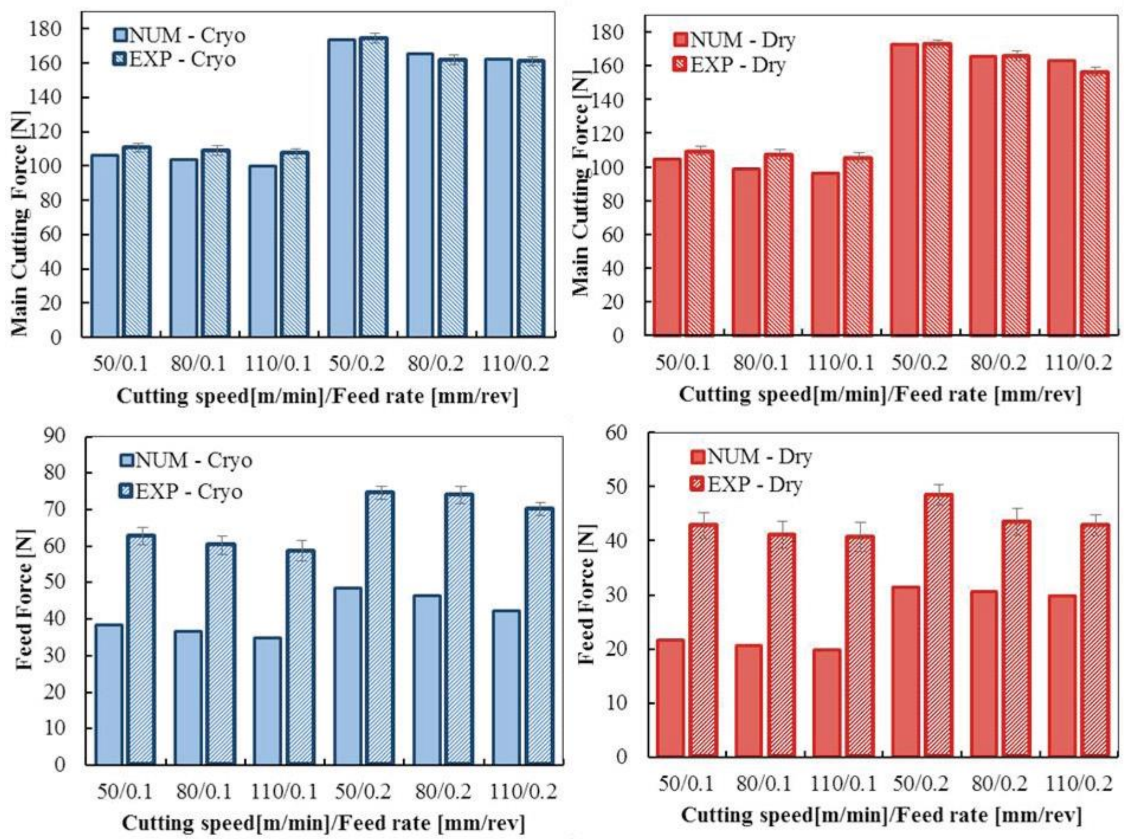

Figure 5. Comparison between Experimental and Estimated Cutting Forces during Dry and Cryogenic Machining (Bordin *et.al.*, 2015).

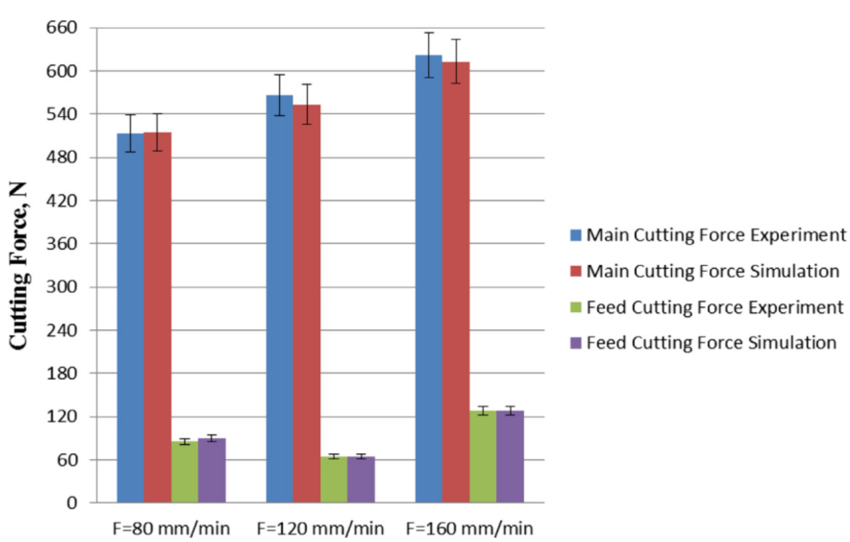

Figure 6. Comparison between Measured and Predicted of Cutting Force Components for Face-Milling on The Titanium Alloy (Ti–6Al–4V) (Moaz *et.al.*, 2013).

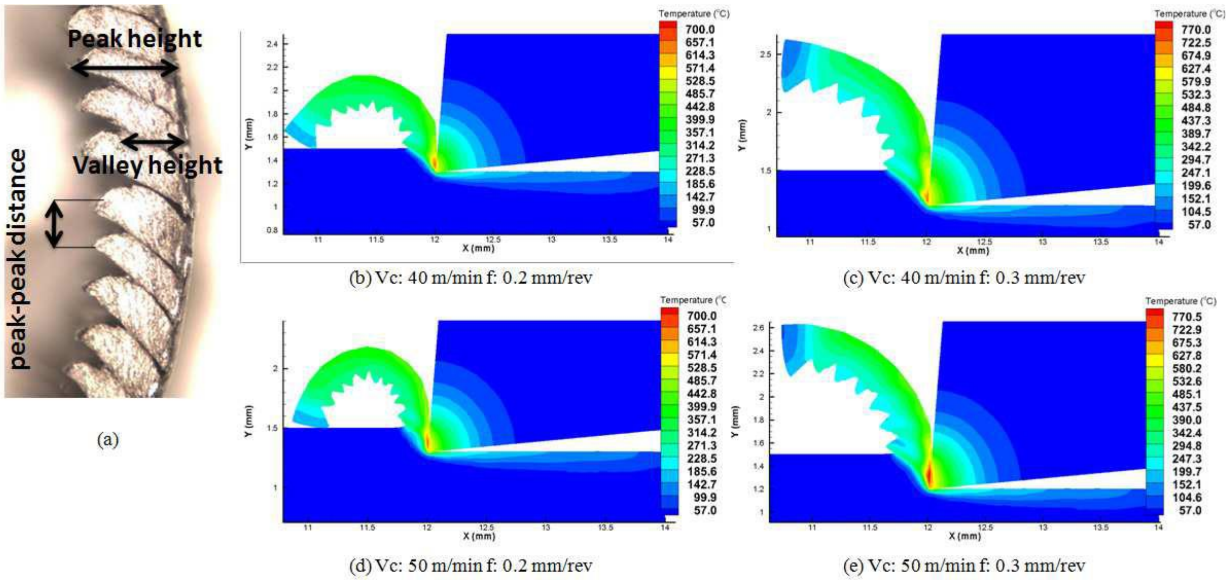

Figure 7. Comparison between Experimental Chip and Simulated Chip at Various Cutting Conditions (Davoudinejad *et.al.*, 2015).